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The ability of pigeons to discriminate
conspecifics, heterospecifics and arbitrary visual patterns

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1 The concept of familiarity in pigeons: Are conspecifics special?

1.1 Abstract

The ability to discriminate a familiar from an unfamiliar individual allows an animal to behave in an appropriate way towards it. This is not only important for conspecifics but also for heterospecifics that live in close proximity. To discriminate on the basis of familiarity an animal has to differentiate using the relations between stimuli and can not use visual similarity rules. It has been shown that pigeons have this ability when categorizing conspecifics. However, whether they can use this concept with another species remains unclear. We examined whether pigeons are able to use the concept of familiarity to categorize photographs of conspecifics and heterospecifics. The results of this study reflect the difficulty of the task. Not all birds were able to learn the training. However, those that were successful used visual patterns to transfer from the training stimuli to photographs of new views, and especially to new pictures of the familiar and unfamiliar birds and did not use the concept of familiarity. This shows how excellent pigeons are in finding visual patterns when presented with a complex discrimination task.

1.2 Introduction

Categorization is of great importance for humans and animals. It allows a reduction of the vast amount of information which is perceived in daily life and this reduction is necessary for cognitive economy. Categorization takes advantage of the fact that objects in the same category share many properties and behaviours. This is crucial in a variety of natural contexts such as food recognition, predator avoidance and interactions with conspecifics.

The ability to differentiate between known individuals and strangers has the advantage that an animal can respond to them in an adequate way. An efficient and adaptive solution for this would be to categorize on the basis of familiarity. However, using this concept cannot be accomplished by using simple visual patterns. It is a cognitively challenging task, the individual needs to classify the stimuli based on their relations (whether they represent familiar or unfamiliar organisms) rather than their physical resemblance. Much research has examined conspecific recognition, in terms of visual, auditory or chemical cues. There is evidence that reptiles have the ability to discriminate between conspecifics using olfactory

(Aragón, López & Martín 2001, Font & Desfilis 2002 and Hanley, Elliott & Stamps 1999) and visual cues (Ord, Peters, Evans & Taylor 2002; Ord & Evans 2002, Van Dyk & Evans 2007). These lizards are highly territorial and so it is crucial for them to be able to discriminate between known and unknown individuals. In birds it has been shown that chickens (*Gallus gallus domesticus*) tend to aggregate more with familiar rather than unfamiliar flockmates (Bradshaw 1992). Similar results were shown by Dawkins (1996) where chicken prefer familiar individuals as feeding companions. However she also showed that they were not able to transfer this preference when photographs were used. Despite this Brown and Dooling (1992) have shown that Budgerigars (*Melopsittacus undulatus*) are able to discriminate between photographs of different conspecifics by using facial cues. Studies in mammals also indicate that vision plays an important role in conspecific recognition. Chimpanzees (*Pan troglodytes*) and Rhesus monkeys (*Macaca mulatta*) are able to use facial cues to discriminate unfamiliar conspecifics (Parr, Winslow, Hopkins & de Waal 2000), whilst longtailed macaques (*Macaca fascicularis*) can use pictures of different body parts to identify group members (Dasser 1987). Whereas this ability has not only been shown in primates. Coulon and colleagues (2008) demonstrated that cattle (*Bos taurus*) have the ability to recognize individuals on the basis of 2D images. They treated each picture view of the same individual in the same way although they had or did not had previous interacted with it. Also sheep (*Ovis orientalis aries*) have the ability to discriminate between individuals of their own species using pictures of their faces (Kendrick, Atkins, Hinton, Heavens & Keverne 1996).

Presentation of photographs as test stimuli, instead of real objects, is a common method in a large amount of experiments. However, perceiving that a picture represents a real-life object is not a simple task. The animal must achieve dual representation; it needs to mentally represent both the picture and the depicted object itself (DeLoache 2000). Furthermore, one need to consider that the way in which an animal perceives pictures can be different in the way humans do. Various factors, including, for example picture quality, functional properties of the visual system, and the subject's prior experience with pictures can have an influence how they perceive it (Aust & Huber 2006, 2010).

Picture-object confusion is often present in animals. Very recently it was shown that tortoises (*Geochelone carbonaria*) seem to confuse a piece of food and a picture of it (Wilkinson et al. in prep.). Baboons seem not to process the pictures as representations either,

but rather mistook the food and their depiction (Parron, Call, & Fagot 2008). Although, as mentioned above, chickens show the ability to discriminate individuals that are familiar they are not able to do this when pictures or videos are used (Bradshaw & Dawkins 1993; D'Eath & Dawkins 1996). The ability to perceive a picture as a representation of a real-life object has been shown only in a small number of mammals (e.g. *Macaca fascicularis*: Dasser 1987, *Cebus capucinus*: Pokorny and de Waal 2009, and *Ovis orientalis aries*: Kendrick et al. 1996). Aust and Huber (2006) were able to show representational insight in pigeons. This was done by using a “complementary information procedure”, the authors were able to exclude the possibility that the pigeons only use single visual features in the pictures and recognize them in the real objects. Animals were trained to categorize photographs of humans with missing body parts against photographs without humans. Images containing the absent body part were then used in a subsequent test. The pigeons responded more to the stimuli with the absent body parts than to non-representative test stimuli. This suggests that the birds recognized the relation between the incomplete pictures and real-life human beings (representational insight). In a later study the authors showed that real-life experience is of great importance to solve this task (Aust & Huber 2010).

Due to the extraordinary homing ability of pigeons, researchers have focused on examining familiarity categorization using experience with places. Wilkie, Willson and Kardal (1989) trained two groups of pigeons (one experimental group with homing experience and one control group without) on two different landscapes. The familiar landscape pictures were taken of an area that the experimental birds had been trained to home to. The results showed that birds with experience learned significantly faster and also showed better transfer to new views of the locations than birds without experience. A similar setup was used in the experiment of Dawkins, Guilford, Braithwaite and Krebs (1995) where an experimental group was exposed to a location that was later pictured in the operant setup. The control group was exposed to an, for the experiment, unrelated place. However the authors of this experiment were not able to find an effect of prior experience of the pictured location in the transfer tests. Cole and Honig (1994) trained pigeons to distinguish between pictures of two ends of a room in an operant chamber. After learning the task the birds were allowed to look for the food in the actual room. Pigeons for which the food was hidden on the previously rewarded side of the room, reached the criterion faster than those for which the food was placed on the previously negative side. Interestingly there was no difference when tested the other way around (trained in the real room and then transfer to pictures). This last study is of

great interest as it shows that pigeons are able to recognise the similarity between real items and the pictured items.

The first study which introduced photographs of conspecifics was conducted by Poole and Lander (1971). Pigeons had to discriminate between pictures due to presence or absence of pigeons. The subjects learned the categorization and were able to transfer to slides of other breeds. This led to the suggestion that they had formed a representation of their own species. Yet, the birds would also be able to do so by simple feature learning. Later experiments show that pigeons seem to have problems recognizing individual conspecifics when presented as pictures or videos (Watanabe & Ito 1991, Ryan & Lea 1994). In contrast to previous mentioned study, the pigeons of Jitsumori and colleagues (1999) were able to distinguish between conspecifics using videos as stimuli, which led to the assumption that movement is crucial for conspecific recognition. Four years later it was shown that they are able to discriminate between not moving (static) images of unfamiliar conspecifics and generalize to novel angles of the pictured birds (Nakamura, Croft & Westbrook 2003). Furthermore that pigeons are also able to discriminate photographs of conspecifics on the basis of sex (Nakamura et al. 2006). But do the birds in these experiments need to know that it is a conspecific for their discrimination?

Very recently it was shown that pigeons have the ability to discriminate between familiar and unfamiliar conspecifics and generalize to new views of the trained stimuli birds (Specht 2009, Wilkinson, Specht & Huber 2010). Critically, two of the birds were also able to categorize pictures of new (not trained) unfamiliar and familiar conspecifics on the basis of their previous real-life experience. This led to the suggestion that the birds were able to build a concept of familiarity. One of the birds was also able to categorize objects as familiar and unfamiliar, this presumed that the bird had a much more general concept of familiarity that was not only conspecifics. Stephan, Wilkinson and Huber (submitted) showed that pigeons are able to learn the concept of familiarity in objects and expand it to human faces. Two groups of pigeons, one experimental and one control group, were trained to discriminate between familiar and unfamiliar objects. Later in the tests they were presented with pictures of new objects and also with pictures of known and unknown human faces. Only the experimental pigeons were able to solve the tests. This raises the question if pigeons are also able to learn to use the concept of familiarity in another species. A group of jackdaws (*Corvus monedula*) was housed in a nearby aviary and thus made ideal familiar heterospecifics. Even

more interesting is the fact that none of the two birds in the study of Specht (2009) and Wilkinson and colleagues (2010) were able to categorize conspecifics of the nearby aviary as familiar. This summoned the next question, if pigeons are able to learn the concept in animals without having physical contact.

Therefore two groups of pigeons were trained to differentiate between images of familiar and unfamiliar conspecifics and heterospecifics (jackdaws). The experimental pigeons had real-life experience with the familiar pigeons and also with the familiar jackdaws. The second group of pigeons had no visual contact with any of the depicted birds of this experiment. Therefore they served as control group for this study. We expected that all birds will pass the training as previous studies showed that pigeons are really good in discrimination tasks (e.g. Watanabe, Sakamoto, & Wakita 1995, Herrnstein 1979 and Huber & Lenz 1993). After reaching a learning criterion in the training the birds received a generalization test. When the birds passed this test a critical familiarity test followed. In this last test we presented them images of known and unknown pigeons and jackdaws that had never been used as stimulus birds during their previous training. The birds could only pass this test if they use the concept of familiarity and transfer their real life experience to 2D touch screen representations.

1.3 Methods

1.3.1 Subjects

We tested 14 homing pigeons (*Columba livia*) who were divided into an experimental and a control group depending on their real-life experience. The experimental pigeons lived in an outdoor aviary (2 x 3 x 3m) in a flock of 11 individuals. These pigeons had auditory, visual and social contact with each other for at least five months. Prior to the onset of the experiment they had for at least four months visual and auditory contact to four jackdaws (*Corvus monedula*) in the nearby aviary. The pigeons of the control aviary were also kept in an outdoor aviary (1.1 x 2 x 2m) in a flock of eight individuals. The two enclosures were located so that they could not see each other. Furthermore the control pigeons were not able to see the jackdaws (Figure 1). All aviaries are roofed and contain perches and nestboxes to provide shelter for the birds.

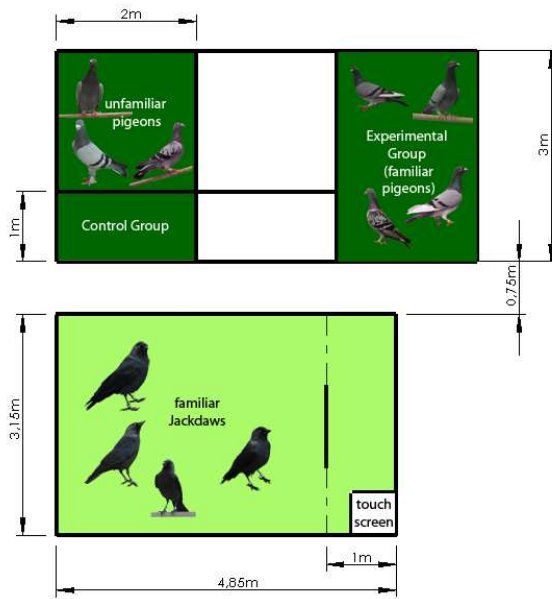


Figure 1: Aviaries of pigeons and jackdaws

During the week, food (mixed grain) was provided during the experiment. The birds also received additional feeding after the training depending on the number of sessions that they had completed. On days when they did not take part in experiments they were provided with an extra ration of food. Water and grit were freely available in the enclosures at all times.

Both groups, experimental and control, had experience with visual discrimination tasks. They had participated in an experiment where they had to discriminate objects on the basis of familiarity (Stephan et al. in submitted), but had never previously categorized photographs of birds.





1.3.2 Stimuli

Colour photographs of pigeons and jackdaws were used as stimuli (e.g. Table 1 and Table 2).

1.3.2.1 Pigeon stimuli

All pigeon stimuli were the same as those used in the experiments of Specht (2009) and Wilkinson et al. (2010). However the experimental pigeons which were used in this experiment did not take part in the previous experiment. The flock mates and the experimental subjects of the experimental group were photographed and used as familiar stimuli birds. The second stimulus set was taken from six individuals who were reared in a visually isolated compartment. None of the subjects had ever seen or interacted with these pigeons.

Table 1: Examples for familiar and unfamiliar pigeons





Examples for familiar pigeons	Examples for unfamiliar pigeons
	
	

1.3.2.2 Jackdaw stimuli

The familiar jackdaw stimuli contained pictures of the jackdaws living in the nearby aviary. They were housed in an outdoor enclosure in a group of four individuals. The pictures of the unfamiliar jackdaws were taken in Bayern. These jackdaws were also housed in an outdoor enclosure in a flock of nine individuals. Both groups of jackdaws were unfamiliar to the control group.

The photographed stimuli contained two categories: first “unfamiliar” stimuli, pictures of stimuli birds (pigeons and jackdaws) that neither the control group nor the experimental group had ever seen or social contact with. The other class of stimuli, “familiar” stimuli, showed birds (pigeons and jackdaws) which were highly familiar to the subjects of the experimental group but unfamiliar to the control group. All stimuli consisted of 12 photographs of each stimulus bird from at least eight different perspectives. All photographs were taken with the same camera (Canon Power Shot G3) to ensure that no visual feature is generated by the quality of pictures could be used to correctly classify the stimuli. Each stimulus measured 3.8 x 3.8 cm. To ensure that no visual features from the background could be used for the classification the natural background of the photographs was removed and replaced by a uniform green one.

Table 2: Examples for familiar and unfamiliar jackdaws

Examples for familiar jackdaws	Examples for unfamiliar jackdaws
	
	

1.3.3 Apparatus

The pigeons were trained in a Skinner Box. The front wall was a 15 inch TFT computer screen that was mounted behind an infrared touch-frame. Food reward was provided using a special feeder, the “grain lifter”. A piston is lifted via an electric motor through the bottom of the test chamber directly below the touch-screen. The Skinner Box was controlled by an C-Lab computer hardware and the CognitionLab Software package (both developed by M. Steurer, Department of Cognitive Biology, University of Vienna, Austria).

1.3.4 Procedure

The pigeons were trained using a two- alternative forced choice procedure. Two photographs were presented on a touch-screen, one positive and one negative. A peck on the positive stimulus led to an auditory signal, the screen was clearing black (normal background colour) and food being provided for 3 seconds. A peck on the negative stimulus led to a different auditory signal and the screen was flashing red for 3 seconds. After this a correction trial, a repeat of the same trial, was presented. This was continued until the bird chose the correct stimulus. Each trial was separated by an intertrial interval of 1 second. During this time the screen was black.

The reward contingencies were counterbalanced. Four of the experimental birds were rewarded for pecking on the familiar bird stimuli, the remaining three for the unfamiliar ones.

To control for possible visual features in the photographs, each control bird was presented with a set of identical stimuli and contingencies as the corresponding experimental bird (Table 3). The control bird which was corresponding to Toby died shortly before the experiment started. Unfortunately there was no other bird that had the correct preconditions (did not see the familiar, unfamiliar pigeons and the jackdaws in the past), and so there was no control for these specific set of stimuli combinations.

Table 3: Reward contingencies for all individuals

Reward contingency	Experimental group	Control group
Familiar (S+)	Mr.Speckle	KiraGru
	BobbyTim	Claire
	Snape	Dr.Wilson
	Toby	-
Familiar (S-)	Matahari	William
	Penny	Mag
	Harry	Dr.House

Birds in the same row had the same experimental files (set of identical stimuli in training and test).

1.3.4.1 Training

Pictures of two familiar and two unfamiliar pigeons and jackdaws were used in the training. Only 10 of the 12 views of each bird served as training stimuli. A training session consisted of 20 novel trials. The birds therefore needed two sessions to see all training pictures. In each trial a picture of a completely unknown bird and one of a familiar bird (for the experimental group) was shown. The order of stimulus presentation and also the pairs varied randomly. The subjects received one to five sessions per day. All birds were trained for at least 30 sessions. After this the training lasted until they reached the learning criterion, 85% (or more) correct in four of five consecutive sessions and at least 75% correct in the remaining one. If a subject did not reach the learning criterion after 200 sessions it was excluded from the rest of the experiment.

1.3.4.2 Generalization Test

Each subject that reached the learning criterion was given a generalization test in which it received the remaining two views of the training stimuli birds. Test sessions consisted of 24 trials 20 training trials with four randomly intermixed test trials. Each test trial contained a

novel picture of one unfamiliar and one familiar (to the experimental group) stimulus bird. The specific stimulus which was used varied randomly across the subjects. Each stimulus was presented four times; every second session combined with a different picture. All in all the birds received 32 test trials over eight test sessions. Pecking on a test stimulus did not result in differential feedback so that the pigeons were not able to learn about them. A subject was given two opportunities to pass the test. If it failed, it was excluded for the rest of the experiment.

1.3.4.3 First familiarity test

This second test examined whether the pigeons were able to discriminate between the birds on the basis of familiarity. Subjects were presented with one entirely unknown pigeon and jackdaw and one familiar pigeon and jackdaw (to the experimental group). These birds had never previously been shown as photographic stimuli to the subjects. All 12 views of the four birds (jackdaws and pigeons) were used. The test trials were prepared in the same manner as described above. Each stimulus was shown two times in different combinations. All in all the subjects received 48 test trials over 12 sessions.

1.3.4.4 Second familiarity test

The results of the first familiarity test were inconclusive, an additional bird of each condition was added to the test stimuli. The new test stimuli were randomly intermixed with the old ones. In contrast to the first familiarity test we also paired the species (familiar pigeon vs. unfamiliar pigeon and familiar jackdaw vs. unfamiliar jackdaw). The subjects received 96 test trials in 24 sessions. Some of the birds had a break of more than a month between the first and the second familiarity test they received retraining sessions until they therefore reached the learning criterion again.

1.4 Results

1.4.1 Acquisition

1.4.1.1 Experimental Group

Only four of the seven experimental birds (Toby, Mr. Speckle, Bobby Tim and Harry) reached the learning criterion (Figure 2). The amount of sessions they needed differed between birds.

The other three individuals (Penny, Snape and Matahari) did not reach the criterion by the 200th session, and were excluded from further testing.

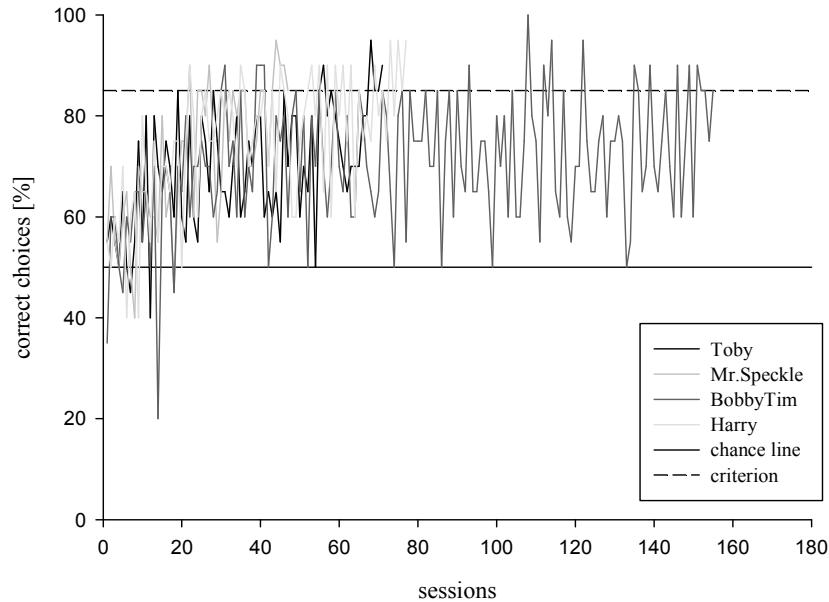


Figure 2: Acquisition curve from the experimental birds which reached the criterion. Spotted line is the criterion and black line is chance. Toby, Mr. Speckle and BibbyTim were rewarded for the familiar and Harry for the unfamiliar stimulus birds.

The experimental birds that reached the learning criterion showed a significant increase in performance between the first and the last ten training sessions in the stimulus conditions “pigeon” (familiar versus unfamiliar pigeon, $T(4)=-6.29$, $p<0.05$), “jackdaw” (familiar versus unfamiliar jackdaw, $T(4)=-11.74$, $p<0.05$) and “fam_pigeon” (familiar pigeon versus unfamiliar jackdaw, $T(4)=-10.46$, $p<0.05$). In these stimulus conditions the pigeons performed at chance level in the first ten sessions and above chance during the last ten (Figure 3). Interestingly, there was no increase of the performance when a familiar jackdaw was presented with an unfamiliar pigeon ($T(4)=-2.33$ $p>0.05$, Figure 3).

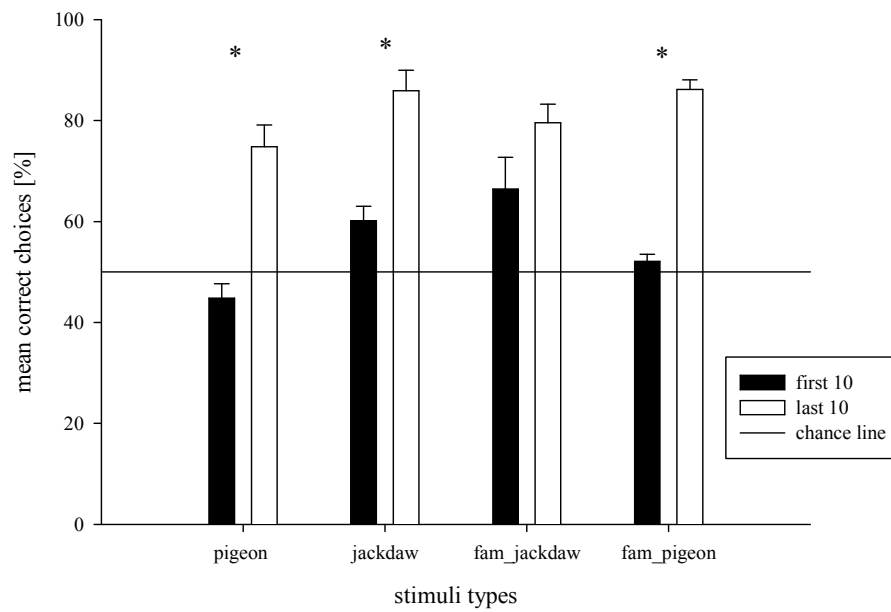


Figure 3: Comparison of the mean correct choices of all experimental birds in the first and last 10 sessions of the training, depending on the stimuli combination (pigeon: familiar vs. unfamiliar pigeon; jackdaw: familiar vs. unfamiliar jackdaw; fam_jackdaw: familiar jackdaw vs. unfamiliar pigeon; fam_pigeon: familiar pigeon vs. unfamiliar jackdaw). T-test: ** $p < 0.01$

1.4.1.2 Control Group

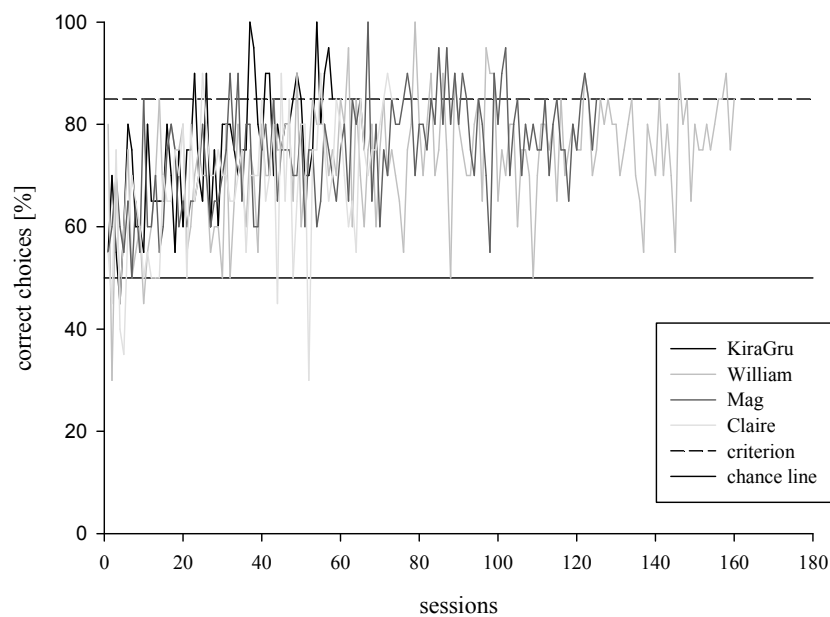


Figure 4: Acquisition curve from the control birds which reached the learning criterion. Spotted line is the criterion and black line is change. KiraGru and Claire were rewarded for the familiar Mag and William for the unfamiliar stimulus birds.

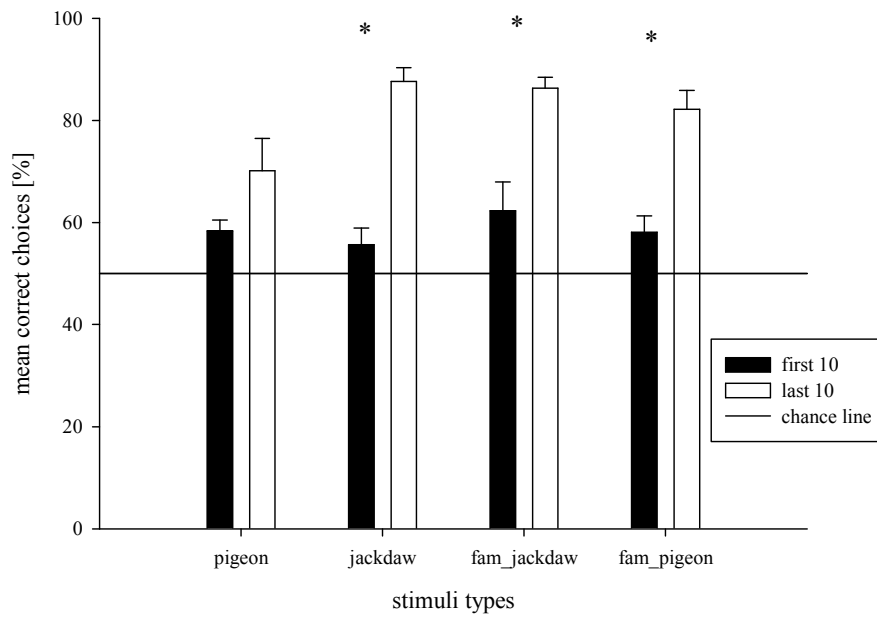


Figure 5: Comparison of the mean correct choices of all control birds in the first and last ten sessions of the training depending on the stimuli combination (pigeon: familiar vs. unfamiliar pigeon; jackdaw: familiar vs. unfamiliar jackdaw; fam_jackdaw: familiar jackdaw vs. unfamiliar pigeon; fam_pigeon: familiar pigeon vs. unfamiliar jackdaw). T-test: * $p < 0.05$

Only four of the six control birds (KiraGru, William, Mag and Claire) reached the learning criterion (Figure 4). The remaining two birds (Dr.House and Dr.Wilson) did not reach the criterion by the 200th session and were excluded from further testing.

There was a significant increase in the performance of the control birds in the stimuli condition “jackdaw” ($T(4) = -11.43$, $p < 0.01$ *df* 4), “fam_jackdaw” ($T(4) = -3.25$, $p < 0.05$) and “fam_pigeon” ($T(4) = -9.77$, $p < 0.01$). In the first ten sessions their performance was at chance level but in the last ten it significantly increased above chance. In the condition familiar vs. unfamiliar pigeon was no increase of the performance ($T(4) = 9.06$, $p > 0.05$). However, the pigeons did not show a high level performance during the whole training (Figure 5).

There was no significant difference found in the amount of sessions to criterion between the control and the experimental birds ($T(6) = -0.51$, $p > 0.05$). Furthermore there was no difference between the training performances depending on the reward contingencies ($T(6) = -1.28$, $p > 0.05$).

1.4.2 Generalization test

1.4.2.1 Experimental Group

All experimental birds which reached the learning criterion also passed the generalization test (Figure 6). Their performance was significant in the intermixed test trials (Binomial test: $p < 0.05$) and highly significant above chance in the training trials (Binomial test: $p < 0.01$). Mr.Speckle and Toby needed two attempts to pass the test.

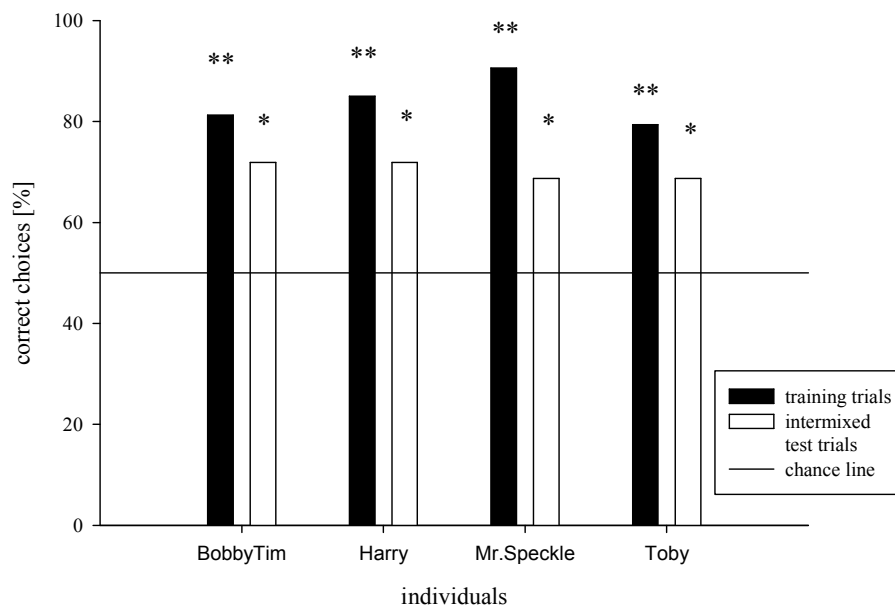


Figure 6: Experimental birds: training trials with intermixed test trials. Binomial test: ** $p < 0.01$, * $p < 0.05$

1.4.2.2 Control Birds

Only three of the four birds that reached the learning criterion also passed the generalization test (KiraGru: $p < 0.01$, Claire: $p < 0.05$, Mag: $p < 0.01$, Binomial test). William did not pass the test in two attempts and was therefore excluded from further testing (Binomial test $p > 0.05$). All birds were highly significant in the training trials (Binomial Test: $p < 0.01$, Figure 7).

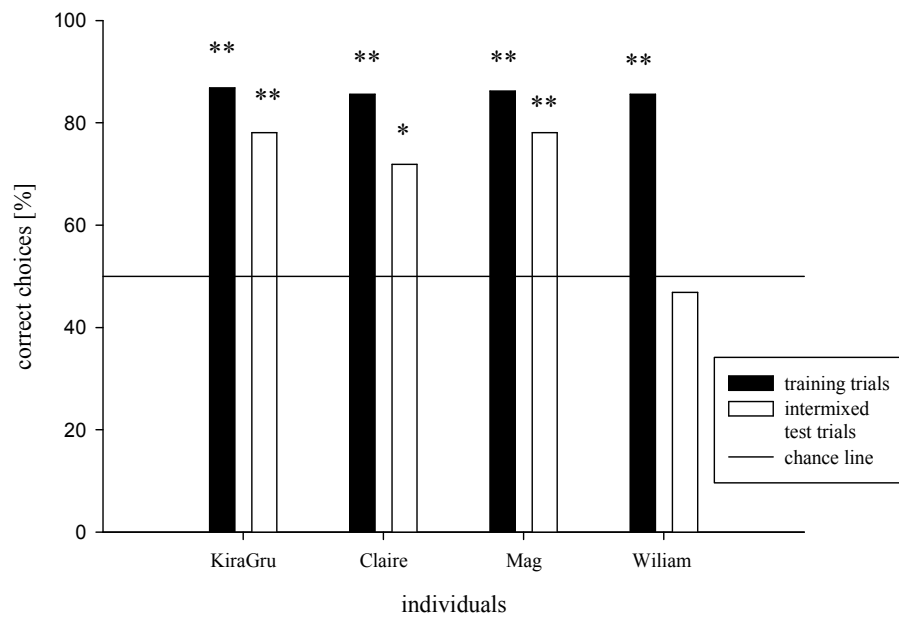


Figure 7: Control birds: training trials with intermixed test trials. Binomial test: ** $p < 0.01$, * $p < 0.05$

1.4.3 First Familiarity test

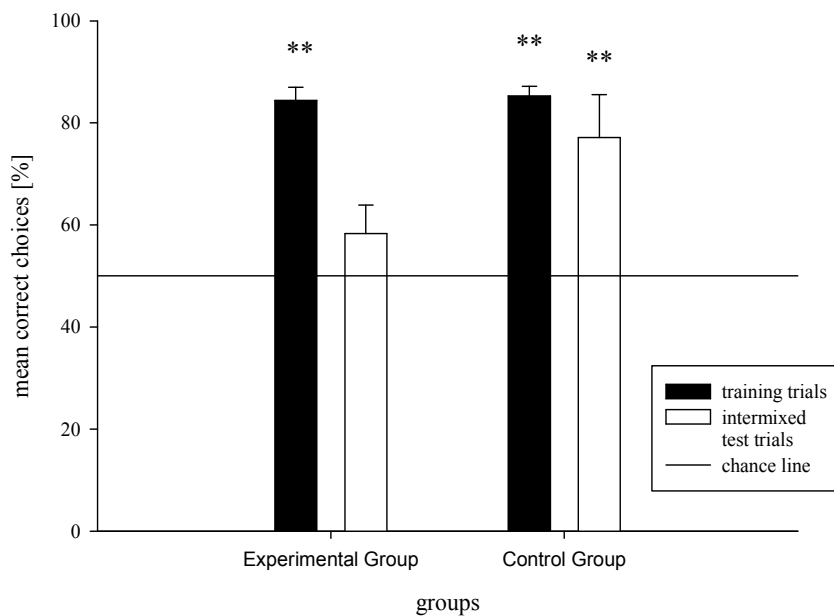


Figure 8: Group results of the first familiarity test. Binomial test: ** $p < 0.01$

In the first familiarity test both groups, experimental and control, were highly significant in the training trials (Binomial test: $p < 0.01$). But only the control group was also highly significant in the intermixed test trials (Binomial test: $p < 0.01$). The experimental group only

reached a mean of 58 percent correct in the test trials (Binomial test: $p>0.05$, Figure 8). To get more insight into which stimulus combination had an influence on the results, the data was split up depending on the combination of test stimuli (Figure 9).

The experimental group was not significant in any of the stimulus combinations (Binomial test: $p>0.05$). In the mixed and the pigeon only combination their performance was on chance level. In the condition where familiar versus unfamiliar jackdaws were presented they were above chance but not significant (Binomial test: $p>0.05$). The control group was not significant when they were presented with a familiar versus an unfamiliar pigeon (Binomial test: $p>0.05$). When they were presented with two different species (pigeon versus jackdaw) they were highly significant (Binomial test: $p<0.01$). In the condition familiar versus unfamiliar jackdaw they were significantly above chance (Binomial test: $p<0.05$, Figure 8).

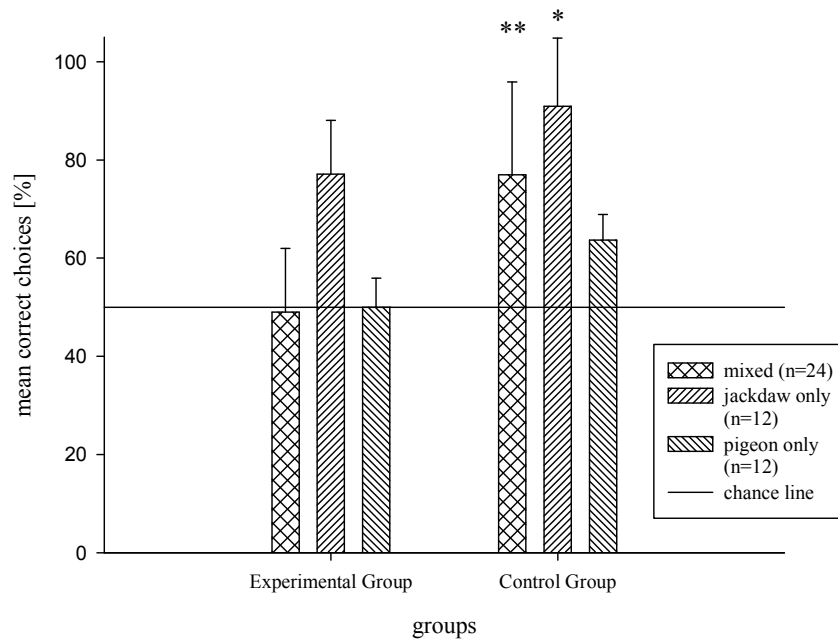


Figure 9: Split up group data concerning the different stimuli conditions of the first familiarity test. Mixed means pigeons versus jackdaw stimuli, pigeon only means familiar versus unfamiliar pigeon and jackdaw only means familiar versus unfamiliar jackdaw. Binomial test: * $p<0.05$, ** $p<0.01$

1.4.4 Second familiarity test

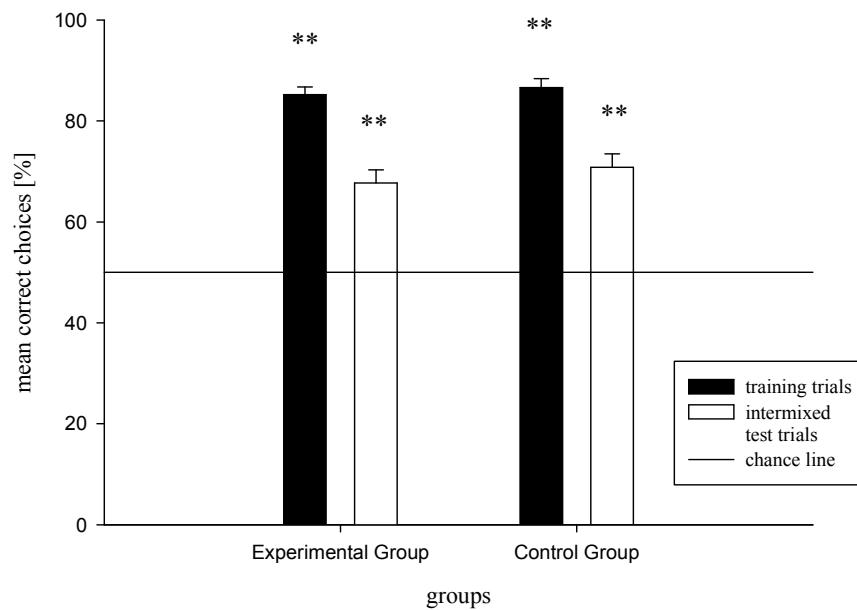


Figure 10: Group results of the second familiarity test. Binomial test: ** $p < 0.01$

In the second familiarity test both groups were highly significant in the training trials and also in the test trials (Binomial test: $p < 0.01$, Figure 10). To examine whether the birds were able to distinguish both, pigeons and jackdaws, the results were again split up into the stimuli combinations (Figure 11).

The results of the split up data showed that both groups had a higher accuracy categorizing the jackdaw than the pigeon stimuli. The experimental group was significantly above chance with the jackdaw stimuli (Binomial test: $p < 0.01$) but not with the pigeon stimuli (Binomial test: $p > 0.05$). The control group was also significantly above chance with the jackdaws (Binomial test: $p < 0.01$) and not with the pigeons (Binomial test: $p > 0.05$, Figure 11).

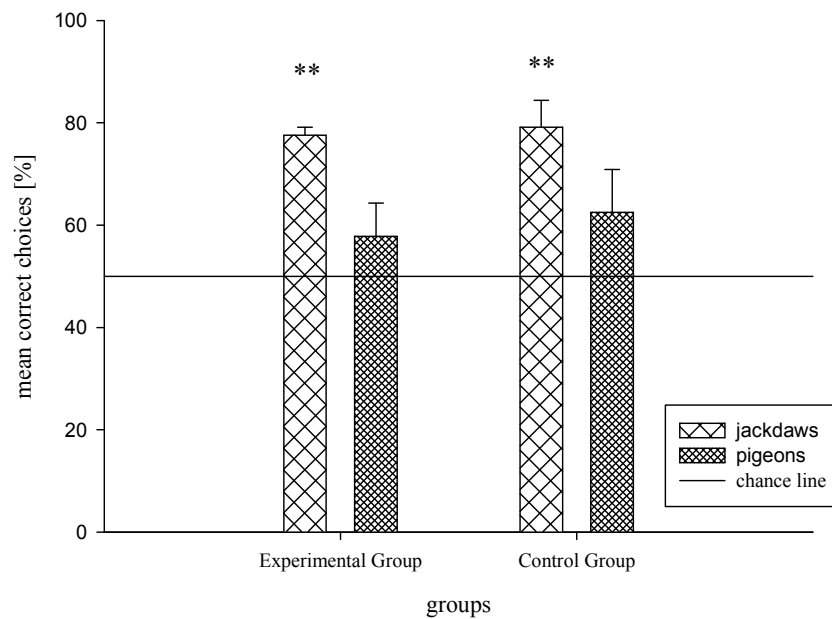


Figure 11: Split up group data concerning the stimuli combination of the second familiarity test. Jackdaws means familiar versus unfamiliar jackdaw, pigeons means familiar versus unfamiliar pigeon stimuli. Binomial test: ** $p < 0.01$

1.5 Discussion

In contrast to previous findings (Stephan et al. submitted, Specht 2009, Wilkinson et al. 2010) the pigeons in this experiment did not use the concept of familiarity to solve the task. Although the birds learned to differentiate between the familiar and unfamiliar jackdaws, the mechanism underlying this behaviour was cognitively simpler. In the final, second familiarity test, not only pigeons of the experimental group were significantly above chance. Yet the individuals of the control group could not have used the concept of familiarity as none of these birds has ever seen the pictured individuals that were used in the study. This result leads to the suggestion that the pictures contained a specific perceptual feature (or features) which helped the birds to distinguish them, without using familiarity.

In the first familiarity test the experimental birds were not able to discriminate the new photographs of the familiar and unfamiliar birds. Yet the pigeons of the control group did differentiate significantly between them. Further analysis of the results revealed that the birds were not able to discriminate all different stimulus combinations. They were able to solve stimulus pairs which contained at least one jackdaw picture. This suggested that there is a feature (or features) in the jackdaw pictures which the birds used for the discrimination. Due

to the small number of test trials used in the initial familiarity test and the unclear results a second familiarity test was carried out. Here the results showed that both the experimental and control group were able to discriminate between the familiar and unfamiliar stimuli (Figure 10). Yet again, looking into the data revealed that they were only able to distinguish between the jackdaw stimuli and performed at chance within the pigeon stimuli. This additionally supports the hypothesis that there was a visual pattern in the jackdaw stimuli which was aiding discrimination in the birds. One possible feature which is apparent to the human eye is that the pictures of the familiar jackdaws seem to be slightly darker than the unfamiliar ones. Many experiments with pigeons have shown that they are able to find specific perceptual patterns which help them to learn a large amount of stimuli. For example pigeons learned to discriminate between pictures containing trees or not (Herrnstein 1979) furthermore chairs, cars and humans (Bhatt, Wasserman, Reynolds & Knauss 1988). This does not alone support the suggestion that the pigeons used a simple feature like brightness to solve the complex categorization task. Yet they used luminance and average intensity as a strong cue to solve an otherwise difficult categorization problem: discriminating between the sexes of humans (Troje, Huber, Loidolt, Aust & Fieder 1999 and Huber, Troje, Loidolt, Aust & Grass 2000). This experiment would strengthen the suggestion that the pigeons in this study are able to use brightness as a cue to first learn the discrimination and then transfer to new pictures in the tests.

However not all of the birds were able to find this pattern(s). Although previous studies were able to show that pigeons can learn a huge amount of stimuli by rote (Cook et al., 2005), five birds in this experiment were not able to learn just of 40 positive versus 40 negative pictures in 200 sessions. But one needs to consider that the stimuli in this experiment did not have obvious patterns which make them easy to learn. Both stimuli classes contained birds at different angles without specific differences despite the species. Furthermore half of the stimuli seem to contain a brightness pattern which was absent in the other half. The obvious difference between the jackdaws and the pigeons could also have disturbed the learning ability of some birds. In the training the presentation of pigeon and jackdaw stimuli was randomized. This was done to avoid simple feature learning. In summary, it is highly complex to learn to discriminate the stimuli in this experiment in comparison to others (Vaughan & Greene 1984 and Cook, Levison, Gillett & Blaisdell 2005). This idea is strengthened by the fact that some birds needed a large number of retraining sessions, between the tests, before they reached the learning criterion again.

Despite these issues more than half of the pigeons were able to reach the learning criterion. Furthermore, except for William, all of them were later able to generalize to new views of the trained birds (Figure 6 and Figure 7). William appeared to have learned the stimuli by rote as he still performed at chance level in the second generalization test attempt. Although the control birds had no experience with the stimulus birds of the training it was suggested that they would be able to transfer to new views of the pictured birds because they share features with the trained stimuli of these birds. Nakamura and his colleagues (2003) demonstrated that the kind of training procedure has an important influence on what the birds learn. When pigeons were trained with only a few exemplars of stimuli birds, they were not able to transfer to novel pictures. By increasing the number of exemplars the pigeons were able to transfer to new photographs. In this experiment the birds were trained with ten pictures of each bird appearing in different angles. However William, despite to the other three birds of the control group, seemed not to be able to find similarities.

Despite using the same pigeon stimuli as were used in the study by Wilkinson and colleagues (2010) the birds did not master the task in the way we predicted. A likely explanation for this could be that the birds were searching for visual features which they apparently found in the jackdaw stimuli. The familiar jackdaw pictures were slightly darker than the unfamiliar ones, but this seemed to be enough to allow them to distinguish between the two sets. The absence of a distinct feature in the pigeon stimuli appears to be the best explanation also why the birds were at chance level in all the tests concerning the pigeon stimuli and maybe also why so many pigeons were not able to reach the learning criterion.

It would be of great interest to examine whether brightness cues had been used as discrimination cues of the jackdaw pictures. To manipulate the pictures and see whether the performance in the test fell to chance level would be one possibility. However it could cause other potential challenges. If the birds discriminate the manipulated photographs, it could be due to another change (not brightness) which the birds perceive different from our perception. One solution would be to manipulate the pictures in the same way. For instance, make the darker ones brighter and the brighter ones darker. This should avoid the possibility of differentiation due to manipulation of the pictures. Similar manipulations have been done by Troje et al. (1999) and Huber et al. (2000). In these studies they had tests in which the average intensity of the stimuli was normalized and ambiguous features, like the average intensity of the faces was exchanged between the training classes. Another possibility for examining

whether brightness was the feature would be to train the birds only on pigeons (where no feature was present) and then test them on the jackdaws and see if the control birds (naive ones) are still able to discriminate and transfer later on. However, a large difference between the training and the test stimuli could affect the birds' performance. To train them on both, jackdaws and pigeons, appears to be a more sensitive method. The best solution would be to take new pictures of the jackdaws under more controlled conditions. Not only should the camera be the same but also the light condition and the person who takes the photographs. Additionally it would be good to normalize the average intensity of the pictures for example in Photoshop (see Troje et al. 1999 and Huber et al. 2000).

In summary, despite of the difficulty of the task eight birds were able to reach the learning criterion. Although there was a visual pattern in only half of the stimulus set the birds were able to transfer to new views of the trained stimulus birds. Interestingly, they were able to use brightness as a pattern, which was only present in the jackdaws, to discriminate completely new pictures of jackdaws significant above chance. All in all the experiment showed that pigeons are excellent at finding visual patterns when presented with a complex discrimination task, and will preferentially use these over abstract concepts.

2 Categorization of high and low selling covers of the New Scientist journal by pigeons: Is there a visual pattern?

2.1 Abstract

Several studies have shown that pigeons have the ability to find visual patterns in sets of stimuli when presented with a discrimination task. In this study we wanted to examine whether pigeons are able to find a visual pattern in high and/or low selling covers of the journal New Scientist. It was hypothesised that visual cues may enhance attractiveness causing people to buy issues in comparison to others. These patterns could then be used to predict future sales of the journal. Four pigeons were trained to discriminate between high and low selling covers and after reaching a learning criterion were presented with a generalization task. All four pigeons were able to learn the stimuli by rote but none of them was able to transfer to new stimuli. Therefore it is suggested that they did not find a common visual feature of the high and/or the low selling covers. Yet there could be something else which influence the human purchasing behaviour which our pigeons were not able to detect.

2.2 Introduction

Categorization takes advantage of the fact that objects in the same category share many properties. By reducing the high degree of complexity of the surrounding world it is an economical way to reduce the cognitive demand on the system. By detecting these common features and properties which are shared by objects or events, it allows an organism, to find connections between them in different situations. This again allows a faster and appropriate reaction.

There are different levels of categorization that an animal or human can use when processing stimuli in their environment. One kind of categorization is to find or build equivalents between the stimuli of the same class on the basis of perceptual similarity. This ability is widely observed in many different species. Studies with monkeys have revealed that they are able to build a category of people (D'Amato & Van Sant 1988) or a category of kingfisher versus other birds (Roberts & Mazmanian 1988). Herrnstein & Loveland (1964) demonstrated first that pigeons were able to learn to preferentially choose pictures which show people in comparison to the ones which do not. They were also able to generalize to new pictures of people. Later on many more studies in pigeons showed that they were able of

perceptual categorization due to similarity of stimulus classes (Watanabe, Sakamoto & Wakita 1995, Herrnstein 1979 and Huber & Lenz 1993).

Another way to solve the discrimination studies mentioned above would be to learn about the stimulus individually (rote learning). Vaughan and Greene (1984) showed that pigeons were able to learn sets of 160 arbitrarily assigned squiggles. Later Cook and his colleagues (2005) showed that pigeons were able to perform at more than 70 percent accuracy with a set of over 1600 images. However the amount of stimuli which is possible to memorize is limited because one needs to remember each exemplar and also the contingency to which it belongs. There is no relationship between the stimuli within a contingency so this kind of processing does not allow an animal to group into classes of new non-identical exemplars (to generalize). Despite this, learning without using categories can be still really important for a huge amount of animals. For instance, in birds which are hiding food (Shettleworth & Krebs, 1986: Clark's Nutcracker remembers more than 3000 hiding places) the ability to remember a large amount of locations is crucial.

In recent years researchers have focused on mapping the relation between formal styles of products and various preferences among consumer groups (Chen & Chang 2006). This has necessarily become a hot topic in design fields. The physical form or design of a product is important for its marketplace success (Bloch 1995). The model of Bloch suggests that the ideal form of a product should evoke positive beliefs, emotions and should approach responses among the members of the target market. However, how consumers differentiate one particular product form style from the other is still vaguely understood. A large amount of research has taken place concerning webpage design, aesthetics and usability (e.g. Hall & Hanna 2004 and Lavie & Tractinsky 2004). Hall and Hanna (2004) were able to show that for example preferred colours (e.g. blues and chromatic colours) led to higher ratings of aesthetic quality and intention to purchase; and that the ratings of aesthetic quality were significantly related to intention to purchase.

Due to the fact that some issues of the journal *New Scientist* are sold better than others, it was hypothesised that the images on the cover could influence whether people choose to buy it or not. As pigeons have an extraordinary ability at finding visual patterns in stimuli they are ideal subjects for investigating this possibility. Additionally to test this hypothesis with an animal model had the advantage that no control was needed in terms of the

content of the issue. Therefore an experiment was set up to examine whether pigeons are able to find a visual pattern in the high selling and/or low selling covers. Additionally four other teams of researchers were in competition to examine possible reasons for the variance in the sales (Giles & Aldhous 2011). Two of them used machine learning, looking for correlations between the attributes of the cover e.g. image, colour, text and so on, and number of sales. Another team did rapid market research. The final team ran a prediction market, which relies on collating human judgment. This one contained of 25 staff of the journal New Scientist who had to express on an online interface how much potential the cover has. The final challenge was to predict the sales for new published issues. For a period of 17 weeks the researchers had to use the cover to predict sales before the magazine came out.

To examine whether a set of features was present in the high and/or low selling covers we trained four pigeons in a visual discrimination task in which they were rewarded for pecking on high or low selling covers (S+ counterbalanced). After reaching the learning criterion they were presented with new covers of the same selling class. If the pigeons were then able to generalize from the learned to the new covers it would suggest that they may have found a pattern which the sets of covers had in common.

2.3 Methods

2.3.1 Subjects

Four pigeons (*Columba livia*) were subjects of this experiment. They were living in different outdoor aviaries in flocks of 8 - 11 pigeons. All aviaries were covered and contained perches and nestboxes to provide shelter for the birds. During the week, on training days, food (mixed grain) was provided during the experiments. The birds also received additional feeding after the training depending on the number of sessions they had completed. On days where they did not take part in experiments they were provided with extra rations of food. Water and grit were freely available in the enclosures at all times. All individuals had experience in a variety of visual discrimination tasks, but had never received stimuli similar to these ones.

2.3.2 Apparatus

The animals were trained using a touch screen Skinner Box. The front wall was a 15 inch TFT computer screen that was mounted behind an infrared touch-frame. Food reward was provided by using a special feeder (a “grain lifter”). After a successful trial the piston was lifted via an

electric motor through the bottom of the test chamber directly below the touch-screen and food was provided. The Skinner Box was controlled by an C-Lab computer hardware and the CognitionLab Software package (both developed by M. Steurer, Department of Cognitive Biology, University of Vienna, Austria).



2.3.3 Stimuli

The stimuli were made up of cover images from the journal New Scientist (issues from 2006 till 2010). They were divided in ten deciles of the whole data set that was ranked according to the sales of the issues. Each decile consisted of 22 covers. Only covers from the top three and the bottom three deciles were used in the experiment. This was to ensure a clear difference between the high and low selling covers. In the training 36 high and 36 low selling covers were randomly chosen by the experimenter (see Table 4 for examples). The remaining ten stimuli of each decile were then used in the generalization test resulting in 30 positive and 30 negative test stimuli (see Table 5 for examples). Each stimulus measured 3x4cm.

Table 4: Examples of high and low selling covers used in the training

good sold training-covers				low sold training-covers			
							
							

Table 5: Examples for high and low selling covers used in the generalization test

good sold test-covers				low sold test-covers			
							
							

2.3.4 Procedure

The stimuli were presented using a two-alternative forced choice procedure. In each trial, two stimuli were presented on the touch screen, one negative and one positive. A peck on the positive stimulus led to an auditory signal, the screen was clearing black (normal background colour) and they had three seconds access to food (mixed grain). A peck on the negative stimulus led to a different auditory signal, the screen was flashing red for three seconds and a correction trial (a repeat of the same trial). This continued until the animal chose the correct stimulus. The interval between the trials was four seconds.

2.3.4.1 Training

The reward contingencies were counterbalanced across the four birds. For two of them (Paula and Trisha) the high selling covers were positive. For the remaining two birds (George and Judith) the low selling covers were rewarded. A training session consisted of 36 trials. In each trial the pigeons were presented with a high and a low selling cover randomly paired. The individuals received one to three training sessions per day. To reach the criterion all birds had to receive at least 20 training sessions and to have a correct first choice in 30 trials (or more) out of 36 trials in four out of five consecutive sessions. The remaining, fifth session, had to be 28 correct (or more) out of 36 trials.

2.3.4.2 Generalization Test

In this test the pigeons received test trials in which the remaining 30 high and 30 low selling covers were presented. A test session consisted of six randomly paired covers. These were pseudo randomly intermixed in the training sessions resulting in 42 trials. Each test stimulus was shown twice resulting in 60 test trials. There was no differential feedback in test trials. That means no auditory signals, no food reward and no correction trials thus the pigeons could not learn about the test stimuli. All birds received one to two test sessions per day.

2.4 Results

2.4.1 Acquisition

All animals learned the training task. George needed 36, Judith 53, Trisha 55 and Paula 34 sessions until they reached the learning criterion (Figure 12). Two of the individuals learned the task faster than the remaining ones. But no difference in terms of reward contingencies

was observed ($T(2)=0.12$, $p>0.5$). A Students t-test showed that there was a significant difference between the first and the last five sessions of training for all four individuals (*George*: $T(4)=-13.02$, $p<0.01$; *Judith*: $T(4)=-11.86$, $p<0.01$; *Paula*: $T(4)=-6.74$, $p<0.01$ and *Trisha*: $T(4)=-7.79$, $p<0.01$).

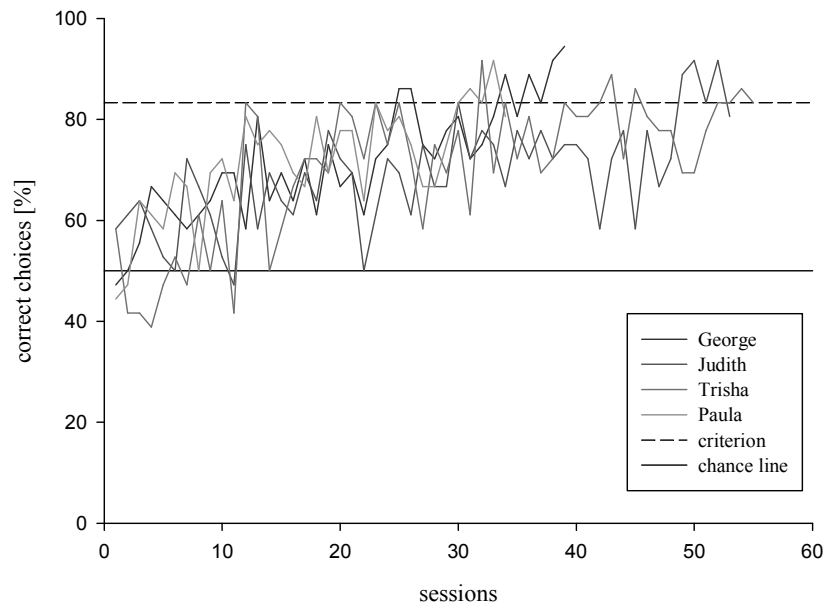


Figure 12: Acquisition of the training of all four individuals

2.4.2 Generalization Test

All birds performed at chance level in the intermixed test trials (Binomial test: $p>0.5$) but they were significantly above chance in the training trials (without the intermixed test trials, Binomial test: $p<0.01$, Figure 13).

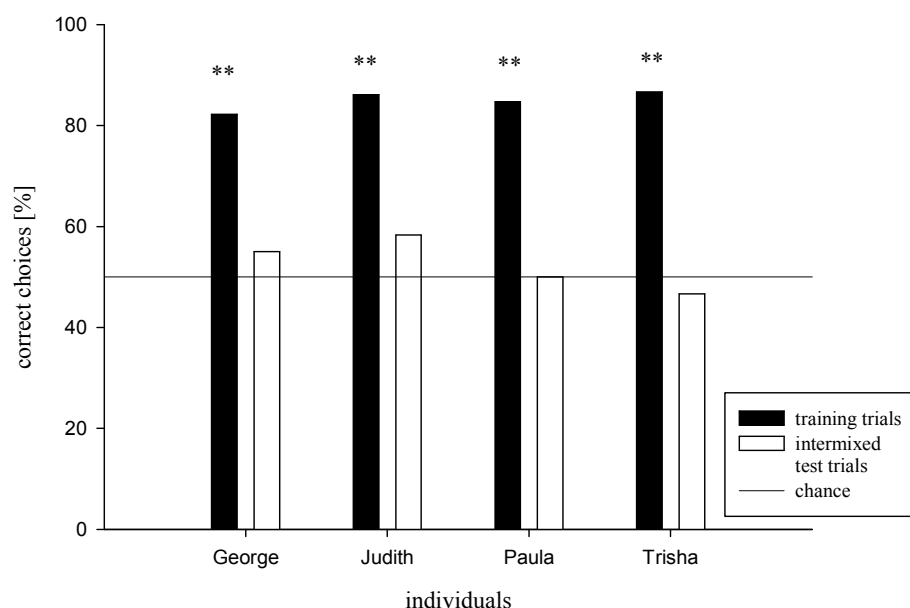


Figure 13: Percentage of the correct choices in the generalization test for all four birds. Binomial test: ** $p < 0.01$.

2.5 Discussion

The results of this study revealed that our pigeons were not able to find a visual pattern in the high compared to the low selling covers of the New Scientist journal. This was in contrast to our predictions. It was thought that it is likely that a feature or sets of features may, in part, control people's purchasing behaviour and that the pigeons in this experiment would be able to detect this and be able to transfer to new introduced covers. However the pigeons in this study were not able to generalize from the learned training covers to new high and low selling ones. This leads to the suggestion that there is no visual feature which the pigeons could use.

All of the birds were able to differentiate between the covers by the end of their training. This was not as surprising as previous studies have revealed that pigeons are able to learn to differentiate a large number of stimuli (Vaughan & Greene 1984; Cook et al. 2005). Their ability to categorize image sets and then generalize to new sets of the same classes has also been shown in a large number of studies (e.g. Herrnstein 1979; Huber & Lenz 1993). Watanabe and his colleagues (1995) have even shown that pigeons can learn to discriminate between paintings from Monet and Picasso and then generalize to new pictures by the same artists. This shows that the birds are able to find common patterns in arbitrary, non-natural stimuli, and are able to find visual patterns, even when they are not present in all stimuli (brightness; as shown in Part 1 of this study).

However, the pigeons in this study were not able to generalize from the learned training pictures to a new set of covers of the same class, and their performances on the test trials were at chance. This suggests that they did not find a common feature to discriminate between the high and low selling covers. The birds needed a large number of sessions to reach the learning criterion. Furthermore the performance in the training trials dropped to chance levels when first presented with the new (untrained) intermixed test covers. Therefore the test sessions had to be repeated until the birds were again significantly above chance in the training stimuli. All in all the results revealed that the pigeons were not able to find common patterns which people use when deciding to buy an issue.

In support of our findings the other forecasting groups were not able to predict the market although they thought they had found a pattern (Giles & Aldhous 2011). One group, for example, applied a statistical algorithm, running a pixel-by-pixel analysis of each cover that revealed the distribution of different colours and tried so to find a pattern which controls purchasing behaviour. They also considered the topics, wording and image types. They found that too much purple in the covers was bad for sales and that writing the title of the issue in black was good for sales. For the first three weeks and also at the end of the contest this group was able to predict the sales surprisingly well. However in one of the middle weeks their forecast was wrong by more than 5500 issues. Also the other groups failed to find a pattern in people's purchasing behaviour. Due to the fact that our pigeons did not find a common feature in the covers they were not tested in the 17 week forecast challenge.

In summary, our pigeons were able to learn 72 arbitrary pictures by rote. They achieved a high level performance. The test revealed that they did this without using a common feature. None of the other research groups were able to predict the sales on the basis of cover pattern, thus it seems to suggest that there is something else influences human purchasing behaviour. It is more likely that the content plays an important role, as scientists choose issues according to the content and only to some extent to a nice cover picture.

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5 Appendix

5.1 Zusammenfassung

Kategorisierung spielt eine wichtige Rolle bei Menschen und Tieren und ist daher ein zentrales Thema der Kognitionsforschung. Kategorisierung erlaubt es, die enorme Fülle an Informationen, welche das Gehirn täglich wahrnehmen muss, zu reduzieren und diese Reduzierung sorgt für kognitive Ökonomie. Es bringt den Vorteil, dass Objekte und Individuen in derselben Kategorie viele Gemeinsamkeiten besitzen. Dies spielt eine wesentliche Rolle in der Nahrungssuche und auch bei Interaktionen mit Individuen der eigenen Art, sowie auch mit denen anderer Arten, wie zum Beispiel bei Partnersuche und Prädatoren Vermeidung.

Im ersten Teil meiner Arbeit wollte ich herausfinden, ob Brieftauben das Konzept der Bekanntheit auch in einer anderen Spezies anhand von Photographien anwenden können. Hierfür wurden zwei Gruppen von Tauben (Experimental- und Kontrollgruppe) anhand einer „two-choice touch screen procedure“ mit Photographien von Tauben und Dohlen präsentiert. Eine Hälfte der Bilder zeigte Tauben und Dohlen, mit der die Experimentalgruppe Erfahrung im realen Leben hat. Die andere Hälfte zeigte unbekannte Artgenossen und Dohlen, mit denen keines der Versuchstiere zuvor Kontakt hatte. Die Kontrollgruppe hingegen hatte keinerlei Erfahrung mit allen abgebildeten Vögeln.

Nicht alle Tauben lernten, zwischen den beiden Stimulussets zu unterscheiden. Die Testergebnisse zeigen weiters, dass die Tiere, welche die Diskriminierung erlernt haben, auf neue Ansichten der Trainingsstimuli generalisieren können. In einem zweiten Test wurden Photographien von Individuen, die nicht als Trainingsstimuli verwendet worden sind, gezeigt. In diesem entscheidenden Test konnten nicht alle Tiere die Bilder richtig klassifizieren. Bei genauerer Betrachtung der Ergebnisse kann man erkennen, dass die Tauben nur die Bilder, auf denen Dohlen abgebildet sind, richtig einordnen. Zusätzlich waren auch die Kontrolltiere dazu fähig. Diese Ergebnisse deuten darauf hin, dass die Tiere bestimmte Merkmale der Dohlenbilder (womöglich Helligkeit) verwendeten und nicht das Konzept der Bekanntheit.

Der zweite Teil der Arbeit beschäftigt sich mit der Fragestellung, ob Tauben fähig sind, zwischen gut und schlecht verkauften Auflagen des Journals „New Scientist“ zu

unterscheiden. Ziel war es herauszufinden, ob es ein bzw. mehrere Merkmale in den Auflagen gibt, durch welche Konsumenten beeinflusst werden, diese zu kaufen bzw. nicht zu kaufen. Vier Tauben wurden trainiert zwischen Covers von alten Auflagen zu unterscheiden. Anschließend wurden sie getestet, ob sie weitere Covers (welche nicht im Training enthalten waren) richtig einordnen können.

Alle Brieftauben waren fähig die Trainingscovers zu lernen, jedoch keine hat es geschafft, die neuen Covers richtig zu klassifizieren. Auch andere Wissenschaftler beschäftigten sich mit der gleichen Fragestellung (mit unterschiedlichen Methoden), aber keinem ist es gelungen, eine exakte Vorhersage zu treffen. Diese Ergebnisse schließen darauf, dass es kein eindeutiges Merkmal gibt, welches das Kaufverhalten der Menschen erklären kann.

Zusammenfassend kann man sagen, dass Brieftauben die Fähigkeit besitzen, schwere Diskriminationsaufgaben zu lernen. Weiters besitzen sie die bemerkenswerte Eigenschaft, gemeinsame visuelle Merkmale in Stimulusklassen zu erkennen (Bsp. Helligkeit) und verwenden diese dann, um neue Stimuli in diese Klassen einzuordnen. Zusätzlich konnte gezeigt werden, dass sie einfache Bildeigenschaften zu verwenden suchen, wenn die Aufgabe zu schwierig wird, zum Beispiel auf abstrakten Relationen (wie „Bekanntheit“) beruht.

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5.4 CURRICULUM VITAE

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2011 – present	Current research: Causes and consequences in animal social network structure , School of Life Sciences, University of Lincoln <u>Supervisors:</u> Dr. T. Pike, Dr. O. Burman, Dr. A. Wilkinson, and Dr. L. John
2010 – 2011	Master thesis: The ability of pigeons to discriminate conspecifics, heterospecifics and arbitrary visual patterns , Department of Cognitive Biology, at the University of Vienna <u>Supervisors:</u> Prof L. Huber and Dr. A. Wilkinson

- 2010 Internship: **The ability of jackdaws to discriminate arbitrary visual patterns**, Department of Cognitive Biology, at the University of Vienna
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- 2010 Collaboration with the journal 'New Scientist': **Categorization of high and low selling covers of the New Scientist Journal by pigeons (*Columba livia*): Is there a visual pattern?**, Department of Cognitive Biology, at the University of Vienna
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- 2010 Internship: **Social learning in the red-footed tortoise (*Geochelone carbonaria*)**, Department of Cognitive Biology, at the University of Vienna
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- 2010 Research practical: **Radial-arm maze navigation of red-footed tortoises**, Department of Cognitive Biology, at the University of Vienna
Supervisors: Prof L. Huber & Dr. A. Wilkinson
- 2009 Bachelor thesis: **Hive behaviour of foraging bees when prevented from depositing pollen**, University of Graz
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AWARDS

- 2008/2009 **Study grant awarded for academic excellence**, University of Graz

PUBLICATIONS

- Paper Wilkinson, A., **Kleinhappel, T.**, & Huber, L. (in prep.). Do social cues control gaze following behaviour in the red-footed tortoise (*Geochelone carbonaria*)?
- Poster **Kleinhappel, T.**, Mueller, J., Wilkinson, A., Hall, G., & Huber L. (2011). Red-footed tortoises navigating a radial arm maze, 2nd TOK conference of COMPCOG.
- Kleinhappel, T.**, John, L., Burman, O., Wilkinson, A., & Pike, T. (2012). Causes and consequences of social network structure of three-spined sticklebacks, EGI Student Conference, Department of Zoology, Oxford.